THE ECONOMIC FEASIBILITY OF MODIFIED FEED AND RUMEN MANAGEMENT TO REDUCE GHG EMISSIONS

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This paper examines and assesses possible methods of controlling ruminant methane emissions. Ruminant livestock production represents a significant source of methane emissions. Methane is produced as a by-product of rumen fermentation. Alternative methods of control include direct management of the rumen and its contents, dietary adjustments, and improved animal productivity. While improved productivity seems to hold the greatest promise in terms of adoption by livestock producers, there is a need for research related to the costs and cost effectiveness of the alternative methods of control.

1. INTRODUCTION

There is ongoing scientific debate regarding the existence of climate change. However, there is no doubt that atmospheric concentrations of "greenhouse gases" (GHG) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O) and chlorofluorocarbons (CFCs) have increased over time, at least in part as a result of human activities (i.e., anthropogenic emissions) (Houghton et al 1992). It is hypothesized that these gases contribute to the greenhouse effect; that is, they trap and absorb outgoing infra-red radiation, resulting in increased temperatures. Agriculture is a major contributor to anthropogenic emissions of GHGs. Within agriculture, ruminant production is a significant source of methane emissions, through exhalation or eructatation and through decomposition of manure.

This paper addresses issues and questions related to the direct production of methane by ruminants. Scientific research has identified the process by which methane is produced, as well as factors contributing to the rate of that production. Research has also identified and

examined methods by which these emissions may be controlled or reduced. However, unanswered questions remain. Are any of these approaches viable from a practical management perspective? Are any of these methods "cost effective and efficient" in terms of their ability to reduce the impact of livestock production as a source of GHGs? These questions provide the focus of the discussion in this paper.

This paper has three overall objectives. The first objective is to review the current state of knowledge, both scientific and economic, related to the issue of methane emissions by ruminants. The second objective is to identify any information gaps that need to be addressed in order to provide answers to the questions outlined above. Finally, this paper will suggest possible research strategies that may be used to fill these gaps.

2. BACKGROUND

2.1 Methane as a GHG

As a contributor to potential global warming, methane is second to carbon dioxide in importance. On a per kilogram basis, it is more potent than carbon dioxide in terms of its global warming potential. However, it is not as long-lived, lasting approximately 11 years in the atmosphere (carbon dioxide lasts approximately 120 years). Besides its direct effects as a GHG, methane is also involved in chemical reactions in the troposphere that result in the production of carbon dioxide, ozone and/or water vapour, which are also all GHGs.

Atmospheric levels of methane have increased over time. As reported by Houghton et al (1992), atmospheric levels have almost doubled since the turn of the century and are currently 1.72 ppmv. As shown in Table 1, the sources of methane are largely anthropogenic in nature (i.e., approximately 70% of total emissions). Of the anthropogenic total, approximately 46% arises from agricultural activities (representing almost one-third of all methane emissions).[1] The two main agricultural sources are rice paddies and domestic livestock production. The primary sink for methane is atmospheric removal. In the troposphere, methane reacts with hydroxyl (OH) radicals to produce water vapour and carbon monoxide (which is further converted to carbon dioxide).

Table 1 Sources of Atmospheric Methane

Source	Tg/Year[a]	% of Total
Energy Sector	100	19.4
Enteric Fermentation	80	15.5
Rice Paddies	60	11.7
Animal Waste	25	4.9
Domestic Sewage Treatment	25	4.9
Biomass Burning	40	7.8
Landfills	30	5.8
Total Anthropogenic	360	69.9

Natural Sources	155	30.1
Total	515	100

Source: Houghton et al (1992)
[a] 1 Tg = 1 x 10^{12} g

2.2 Ruminants and Methane Production

All animals produce methane as part of the digestion process. Ruminants represent the most significant source of methane emissions within commercial livestock production, contributing 97% of the total for domestic livestock (Johnson and Ward 1996). When feed enters the rumen, microbial fermentation takes place. Methane is produced by bacteria (methanogenesis) as a by-product of the fermentation process. These methanogenic bacteria use methane production as a mechanism to generate ATP (Mathison et al 1998).

It is known that several factors influence the rate of methane production in ruminants, including breed and species, environmental conditions and diet. However, exact relationships for some of these factors are unknown. For example, there is limited information concerning the impact of breed on methane production. There is also limited information regarding the impact of environmental conditions, specifically temperature. Mathison et al (1998) indicate that the physiology of ruminants would suggest that methane production is reduced with lower environmental temperatures. This is due to reduced digestion rates in the rumen and faster passage of materials through the rumen in colder temperatures (Westra and Christopherson 1976). The evidence from empirical research is conflicting, however.

There is more conclusive evidence concerning the impact of diet. It is known that methane production decreases with increased levels of grain in the diet (Johnson and Johnson 1995). Methane production is also influenced by forage characteristics, including stage of maturity, method of preservation, species and climate (McAllister et al 1996). For example, methane production is decreased with increased use of ensiled forages, or with increased use of finely ground or pelleted diets as opposed to coarsely chopped forages. Less frequent feeding also depresses methane production (Sutton et al 1986), as does increasing the feeding level (Blaxter and Clapperton 1965). The explanation as to why these factors affect methane production vary, but relate primarily to increasing the speed of passage of materials through the rumen and/or shifting the pattern of fermentation and changing the acetate:proprionate ratio.

3. CONTROL OF METHANE EMISSIONS - SCIENTIFIC RESEARCH

3.1 Rumen Management

One means of controlling methane production in the rumen is to inhibit methanogenesis through the use of compounds such as halogenated methane analogues (Mathison et al 1998). These compounds (e.g., choloroform, carbon tetrachloride) work through a variety of mechanisms and tend to be very powerful methane inhibitors. However,

there are concerns about this approach, including adaptation by the methanogenic bacteria, toxicity of the compounds to the host animal, and negative effects on digestion and performance (Van Nevel and Demeyer 1996). As a result, there have been no practical applications of this approach to date.

An alternative rumen management approach is defaunation, which is the removal of rumen protozoa. This results in reduced methane production due to the presence of a symbiotic relationship between the rumen protozoa and certain species of methanogenic bacteria and reduced digestion of fibre in the rumen (Mathison et al 1998). Again, however, there are concerns with this approach relating to a reduced ability to digest fibre by the ruminant and the toxicity of many defaunation agents. As a result, there have been no practical methods of applying this approach developed as of yet.

A third rumen management method is the use of ionophores, which are polyether antibiotics. Ionophores have been shown to reduce methanogenesis by inhibiting the growth of some methanogens and rumen protozoa (Van Nevel and Demeyer 1977). There is significant potential for this method of controlling methane production, particularly as ionophores also increase feed efficiency (i.e., improved productivity as discussed below). These compounds have been commercially produced as feed additives for beef cattle (e.g., monensin and lasalocid). There is a lack of information, however, as to the long term adaptability of methanogens and possible strategies to avoid this problem.

3.2 Dietary Management

As noted above, dietary considerations affect the rate of methane production in ruminants. Various nutrition management strategies may therefore be considered in attempting to reduce methane emissions. These include increasing the grain/forage ratio in rations, changing the type of forage included in rations (e.g., using ensiled instead of dried forages), less frequent feeding, etc. Another dietary management approach is the inclusion of unsaturated fatty acids in ruminant diets. These substances have toxic effects on ruminal microorganisms and also reduce the rate of fermentation in the rumen. The net effect is to reduce the rate of methanogenesis in the rumen (Johnson and Johnson 1995). As long as they are carried out within the constraints of meeting required nutrient levels (e.g., energy, protein), these strategies represent practical approaches to methane emission management.

3.3 Improved Productivity

There is evidence that improved animal productivity also contributes to reduced methane emissions from the livestock sector. Specifically, reduced methane emissions can be attained from reduced maintenance requirements per unit of production, and from improved feed conversion efficiency over and above maintenance requirements. This increased productivity may arise from improved management in areas such as nutrition, genetics, health and breeding. In general, these strategies do not result in reduced rates of methane production within the rumen. Instead, methane production is reduced on a per unit of milk or beef basis. With respect to maintenance requirements, approximately 50% of methane emissions from dairy cattle and 70% of methane emissions from beef cattle are attributable to

energy required to maintain livestock (US Environmental Protection Agency 1993).[2] With improved productivity in beef and/or dairy animals, these emissions are spread over more units of production. Similarly, with improved feed conversion efficiency for production purposes, total emissions per unit of production are also reduced.

Several methane emission control strategies related to improved productivity have been identified. These involve improved management of nutrition, genetics and health and breeding. For example, proper ration balancing can improve feed conversion efficiency in cattle. There is a linkage here with dietary management strategies as well. For example, ration formulation incorporating proper nutrient balances and consideration of the impact of grain/forage ratio on methane production can result in both a reduced rate of methane production in the rumen and reduced methane production per unit of milk or beef production. Similarly, attention to genetic management (e.g., use of superior sires and/or embryo transplants) and health/breeding management (e.g., improved heat detection, use of pregnancy checks) can also improve productivity with corresponding decreases in methane emissions per unit of production.

Other productivity enhancing agents have been identified and, in some cases, introduced into commercial livestock production. These can also contribute to reduced methane emissions from ruminants. For example, the use of recombinant bovine somatotropin (BST) in dairy cattle can improve milk productivity with a corresponding decrease in methane emissions per hectolitre of milk. In beef cattle, the use of anabolic steroids (e.g., progesterone, testosterone) to redirect energy from fat production to protein production, or the use of ionophores (discussed earlier) to increase feed conversion rates, can have an effect on methane emission rates per unit of beef production. The majority of these methods of improving productivity (i.e., improved management, productivity enhancing agents) are viable from the perspective of being able to implement them within commercial livestock operations.

4. CONTROL OF METHANE EMISSIONS - ECONOMIC RESEARCH

From the perspective of economics, there are two relevant questions that can be asked regarding the strategies and methods of reducing methane emissions discussed in the previous section. First, is it economically practical for commercial livestock production units to adopt these approaches? Secondly, are these approaches cost effective from the perspective of reducing methane emissions? In other words, what are the costs per unit of methane removed and how do these costs compare to other alternatives?

The information available concerning the practicality and potential efficiency associated with on farm adoption varies by methane emission control method. Little farm management research has been done regarding the various rumen management techniques. This is primarily due to the fact that, with the exception of ionophores, these methods have not been developed to the point of practical application.

In contrast, more attention has been given to the farm management implications of dietary management approaches and methods of improved productivity, although the focus of the research has not been on the potential of these approaches for controlling methane emissions. It is well established that improved management (i.e., nutrition, breeding, etc.), tends to be cost efficient resulting in improved farm performance. The viability of dietary management as a means of controlling methane emissions often depends on the relative costs of ration ingredients and the value of the resulting product.

There has also been research conducted on the viability of various productivity enhancing agents. The results indicate that they are viable at the farm level, although again much depends on the costs of the technology relative to the value added from it. For example, much analysis has been done concerning the potential impact of BST adoption by dairy farmers in Canada and the US (e.g., Fallert et al 1987, Deloitte Touche 1990). The results generally show positive net benefits to the farmer from adoption of this biotechnology. Similar research has been conducted for other types of productivity enhancing agents, with similar conclusions.

The other economics question relates to the cost per unit of methane removed for specific emission reduction approaches. Which approach is most cost efficient in this respect? How do these costs compare to strategies for other sectors (e.g., rice production, energy industry)? Should the focus of policy makers be on reduction of methane emissions in livestock production, or should that focus be elsewhere? On these questions the literature is relatively silent. Animal science research has given little consideration to costs associated with decreased rates of methane production. Similarly, there is little applied economics research addressing the costs of reducing methane emissions in commercial livestock production. The US Environmental Protection Agency (1993) examines opportunities to reduce methane emissions from livestock production in the US. The focus in this report is on productivity improvements and improved marketing systems. Projections for potential methane emission reductions in the beef and dairy sectors are provided (15 to 25 percent by 2010) including a breakdown by method of reduction. While the methods are referred to as being cost-effective and profitable, there is no indication of the cost required to achieve these reductions.

Drennen and Chapman (1992) report a cost of $352 per metric ton of CO_2 equivalent removed that is attributable to changing cow rations. They suggest that this method of reducing methane emissions is costly relative to non-agricultural alternatives. However, no indication of methodology is provided in the article.

5. INFORMATION GAPS AND RESEARCH STRATEGIES

From the discussion in the previous section, there would seem to be information gaps relating to ruminant methane emission reductions. First, there is a lack of information regarding on-farm costs for specific methods of controlling or reducing methane emissions

from ruminants. This is particularly true for approaches involving rumen management.

The other major information gap is with respect to the cost per unit of methane reduction for the various approaches. There is a lack of complete and accurate information indicating the likely impact on methane emissions achievable from each method. This is particularly important for making comparisons between methods that reduce the rate of methane production by the animal and methods that reduce the rate of emission per unit of milk or beef production. There is also a lack of information regarding the cost of achieving these levels of reduction.

The research strategies necessary to bridge these gaps are relatively straightforward. First, a thorough review and synthesis of scientific research results needs to be undertaken. This will ensure that the technical assumptions made in any economic analysis are as accurate and plausible as possible. A second necessary research strategy is to undertake rigorous budgeting related to the various methane emission reduction approaches. This budgeting will provide cost estimates that are necessary to evaluate the relative viability of these approaches for on-farm adoption. The budgeting results will also provide information necessary to assess the cost effectiveness of the various methods in terms of methane emission reductions.

Finally, it is important to conduct research designed to compare the costs of reducing methane emissions from commercial livestock production with emission reduction costs associated with other areas. These may include other sources of methane emissions (e.g., the energy sector), or sources of emissions for other GHGs. Again, results of this research would provide useful information for policy makers who must decide areas of priority for encouraging reductions in anthropogenic emissions of GHGs.

6. CONCLUDING COMMENTS

Within agriculture, commercial livestock production (particularly ruminant production) has been identified as a significant source of methane, which is an important GHG. Effective methods of reducing methane emissions from ruminants have been identified and studied by scientists. There is no doubt that methane emissions from ruminant livestock production can be reduced through a combination of rumen management, dietary management and improved productivity.

The approach with the greatest immediate promise is improved productivity in beef and dairy production. This strategy has the advantage of reducing methane emissions per unit of production while at the same time having visible and significant advantages from a farm management perspective.

However, caution needs to be taken in proceeding with efforts to encourage adoption of any methane emission reducing strategy. First, there is a lack of information concerning the costs associated with methane emission reductions in ruminant livestock production.

Secondly, it is not known is whether priority should be given to GHG emission reductions from ruminant production, or whether the emphasis should be on reductions in carbon dioxide emissions. Applied economic research needs to be conducted in these areas in order to provide complete information for making recommendations to policy makers in terms of appropriate priorities for activities to prevent and reduce global warming.

NOTES

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[1] [1] The single largest anthropogenic source is the energy sector, including coal mining, natural gas and petroleum industries.

2 [2] It should be noted that these estimates are calculated including energy requirements for bulls and replacement animals as part of total maintenance requirements.